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Please send address changes to Rae Watson. You may use the Literature Order Form at the end of the New Nursery Literature section.

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Nursery Meetings

16th Wildland Shrub Symposium

This symposium will be held May 26 to 27, 2010 at Utah State University in Logan, Utah. Papers on Climate Change, Wildlife, Energy Extraction, Invasive Species, Restoration, Wildfire, Recreation, Livestock Grazing. Social and Economic Aspects, and Shrub Biology are encouraged.

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Forest Nurseries in the Natural State: Biennial meeting of the Southern Forest Nursery Association

This meeting will be held on July 26-29, 2010 in Little Rock, Arkansas.

Early registration will be S300 and late registration S400. Lodging is available at The Peabody Little Rock with single rooms at $88 and doubles at $128 plus tax. A full registration packet will be sent out in April.

Program and exhibitor information is available by contacting Allan Murray at 501-907-2486 or allan.murray@arkansas.gov

Registration services will be provided by Western Forestry and Conservation Association, 503-226-4562 or www.westernforestry.org

Target Seedling Symposium 2010

August 24-26, 2010
Sheraton Airport Hotel, Portland, Oregon

Joint meeting of:
Forest Nursery Association of British Columbia and Western Forest and Conservation Nursery Association

August 24-25

Target Plant Characteristics

August 24

Choice of two field trips

Blooming Nursery: wholesale nursery with Oregon's largest solar thermal energy installation to circulate warm water and heat a 54,000 sq. ft greenhouse.

OR

Conifer Seedling Production: Visit both a container nursery producing a wide array of conifer seedlings primarily for reforestation and a bareroot nursery providing transplants for reforestation projects.

August 25

Hands-on sessions

August 26, 2010

Current and Emerging Technologies

Please contact:
Richard Zabel
Western Forestry and Conservation Association
503-226-4562
or mail to:
Richard@westernforestry.org

Registration information, lodging information, and the full event schedule will be available in April at

www.westernforestry.org

Western Region of the International Plant Propagators Society

This year's meeting will be held in Bellingham, Washington on September 8 - 11, 2010

The agenda is still being developed but will include a wide variety of presentations on all aspects of plant propagation.

For more information go to the following website:
http://www.ipps.org

The Fifth Western Native Plants Conference

This conference will be held on December 7-9, 2010 in Portland, Oregon. This event happens every 3 years and covers challenges and strategies for propagation and restoration of native plants.

A variety of experts will speak about many topics such as invasives, genetics, climate change, monitoring, etc. The first day will consist of an optional all-day field tour of nurseries and restoration projects in the area.

The agenda and more information and registration will be posted at www.westernforestry.org or contact Diane for further information:

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Fertigation - Injecting soluble fertilizers into the irrigation system: Part 2

by Thomas D. Landis, Jeremy R. Pinto, and Anthony S. Davis

The first part of this article in the Summer 2009 issue covered basic mineral nutrition, the 3 components of a fertigation system, and the chemical calculations for formulating your own custom fertigation solutions. In this second and final part, we'll discuss types of fertilizer injectors, fertigation scheduling, and how to check injector function and determine exactly how much liquid fertilizer is going on your crop.

The simplest way to fertigate is to mix a large batch of applied strength solution and just spray it directly on your crops. Some bareroot nurseries fertigate their beds by spraying an applied strength fertilizer solution through a tractor-drawn sprayer (Triebwasser and Altsuler 1995).

Because of the sheer volume of fertigation solution and higher labor costs for mixing and application, this method is only practical in smaller container facilities. One obvious benefit of applying a diluted fertilizer solution is that there is no risk of fertilizer burn.

Types of Injectors

Most fertigation systems use some type of mechanical injector to mix small volumes of concentrated fertilizer solutions into the irrigation water; a wide variety of injectors are available (Table 1). The best and most current information on fertilizer injectors can be found on-line (Kessler and Pennisi 2004; Pennisi and Kessler 2003), and be sure to check the manufacturers websites for the latest information. For example, recent publications mention one injector, the Gewa, but that company has recently gone out of business and only replacement parts are now available.

The simplest and least expensive fertilizer injectors are the venturi types, such as the Hozon (Figure 1A),

Table 1 – Technical specifications for common fertilizer injectors

Brand name	Multiple heads	Injection ratios	Water Flow rate (gpm)	Water supply pipe diameter (in.)	Approx. cost (2010)	Acid injection possible	Remarks
Venturi							
Hozon	No	1:12 to 1:16	Any	0.75	$30	No	Requires 35 psi water pressure
E-Z Flo	No	Varies with model: 1:400 to 1:1,000	Any	Varies with model: 0.75 to 3.00	$50 to $750	No	www.ezfloinjection.com/
Positive displacement hydraulic pump							
Smith MeasureMix	Yes	Varies with model: 1:100 or 1:200	Varies with model: 3 to 200	Varies with model: 0.75 to 6.00	$1,600 to $4,600	Yes	www.smithpumps.com
DosMatic	No	1:50 to 1:200	Varies with Model: 5 to 20	0.75	$500 to $700	Yes	www.DosMatic.com
Dosatron	No	1:50 to 1:500	Varies with model: 0.5 to 100	Varies with model: 0.75 to 2.00	$500 to $2,000	Yes	www.dosatronusa.com
Flow-metered hydraulic or electric pump							
Anderson	Yes	Adjustable: 1: 100 to 1:20,000	Varies with model: 0.75 to 300	Varies with model: 0.75 to 10.00	$800 to $5,000	Yes	www.heanderson.com

which continuously injects stock solution at an approximate 1:16 ratio. As water passes through the Hozon, it creates a negative pressure that sucks the fertilizer solution from the stock tank (Figure I B). One limitation is that a water pressure of at least 35 psi (pounds per square inch) is needed to create sufficient suction. Siphon injectors can be used to apply other water-soluble chemicals, such as insecticides and fungicides, but cannot be used to inject acids (Pennisi and Kessler 2003). More sophisticated injectors, such as the Smith Measuremix* (Figure 1C), feature a water motor that injects stock solution at a specified ratio. For example, an injector with a 1:100 ratio injects one part fertilizer stock solution for every 100 parts of irrigation water (Figure 1D). Many of these injectors have separate heads to inject two or more solutions and some models have plastic parts that that are compatible with acid injection. Again, check the web publications and manufacturer website for specifications (Table 1).

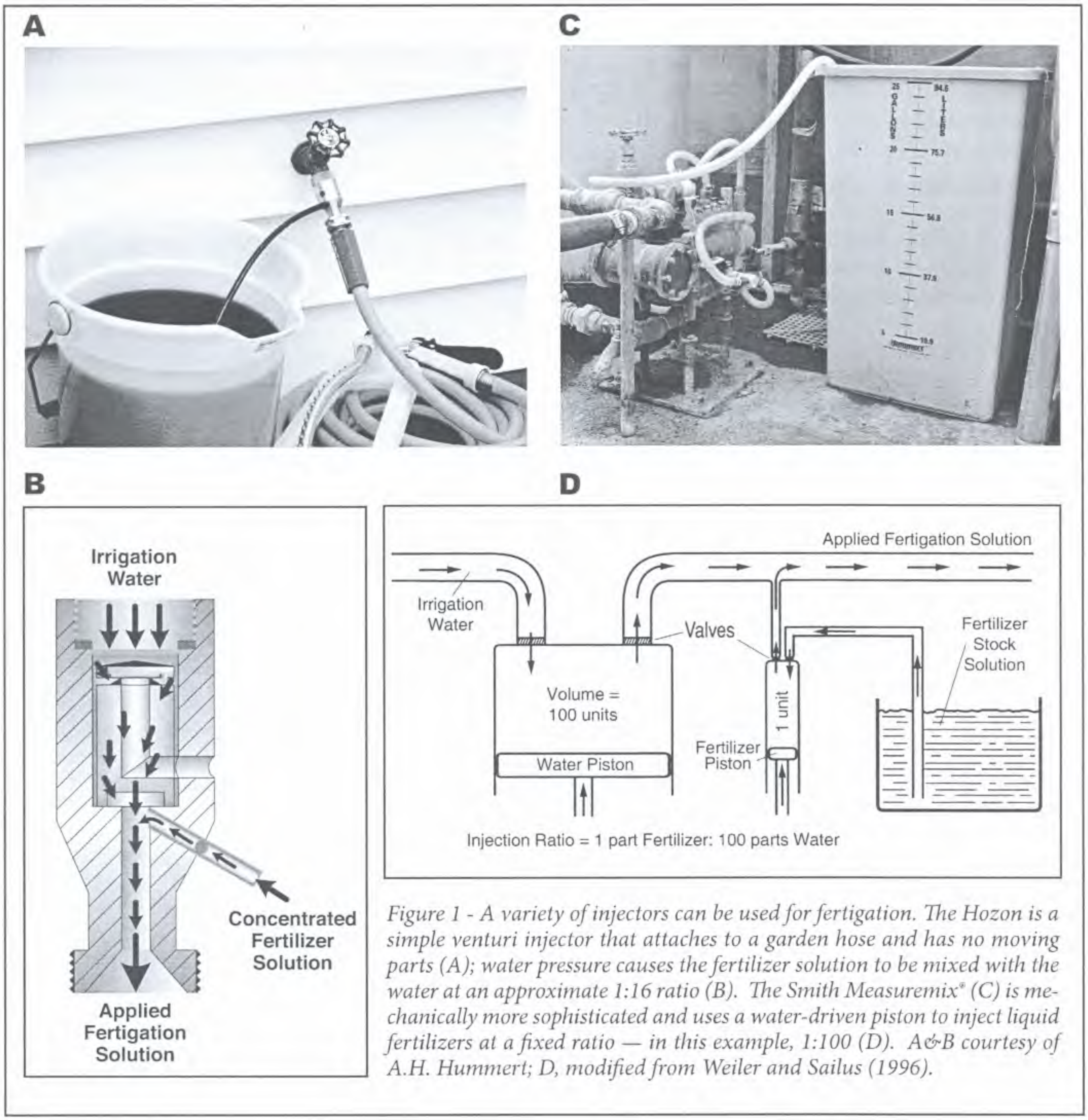


Figure 1 - A variety of injectors can be used for fertigation. The Hozon is a simple venturi injector that attaches to a garden hose and has no moving parts (A); water pressure causes the fertilizer solution to be mixed with the water at an approximate 1:16 ratio (B). The Smith Measuremix® (C) is mechanically more sophisticated and uses a water-driven piston to inject liquid fertilizers at a fixed ratio — in this example, 1:100 (D). A&B courtesy of A.H. Hummert; D, modified from Weiler and Sailus (1996).

Several things should be considered before purchasing an injector (Kessler and Pennisi 2004; Pennisi and Kessler 2003; Weiler and Sailus 1996):

Size and complexity of your nursery - Small nurseries growing a few species with hand watering or with an irrigation system with only a couple of zones can get by with a simple and inexpensive injector such as the Hozon or E-Z Flo. However, as the number of crops and the area to be fertigated increases, more sophisticated injectors are required. If you haven't done so already, it's a good idea to separate your different crops into nutrient requirement zones such as low, medium, and high. Native plant crops vary considerably in their response to fertilization, especially nitrogen, so grouping species by fertility zones makes fertigation much easier and more efficient.

Water flow rate - Because injectors supply a proportionate amount of liquid fertilizer to a given amount of water, you must know how much water your irrigation system can supply per unit of time. Flow rates can be divided into three categories based on gallons per minute (gpm): low (0.05 to 12 gpm), medium (12 to 40 gpm) or high (> 40 gpm). If you don't know your water flow rate, there are a couple of ways to find out. The simplest is to turn your irrigation on full, and measure how long it takes to fill a container or tank of known volume. Dividing the volume in gallons by the time in minutes gives you gpm.

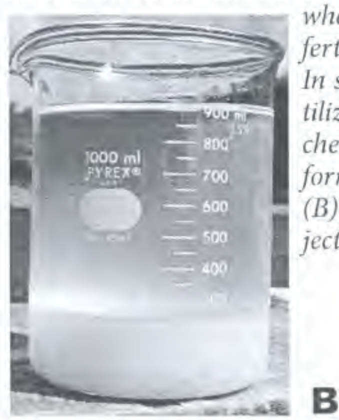
If your nursery has a permanent irrigation system, then you hopefully have an in-line water meter that measures total volume usage; if not, we'd recommend getting one installed. Knowing your irrigation flow rates is essential to effective fertigation; writing down the starting and ending water usage along with the amount of stock solution consumed in a daily log book is an easy and effective way to confirm the actual injection ratio and check if the injector is working properly.

Injection ratio - This is simply the ratio of the amount of fertilizer injected per volume of irrigation water and most fertilizer injectors can be ordered with a wide variety of injection ratios (Table 1). Most injectors have a fixed injection ratio and the most common are 1:100 or 1:200, but some brands feature adjustable injection ratios. In-line venturi injectors used in hand watering have relatively low injector ratios. For automated irrigation systems, injectors with ratios less than 1:100 aren't practical because a very large fertigation tank would be required. On the other hand, using injectors with ratios >1:200 means that the fertilizer solution must be very concentrated, which leads to insolubility problems.

Multiple injector heads - Simpler injectors such as the Hozon can handle only one fertilizer stock solution at a time, but many fertilizer injectors can be ordered with two or more injection ports, or heads (Table 1). Commercial brands of soluble fertilizer can be mixed in a single stock solution tank so an injector with one head is adequate. However, when injecting acids to correct high water pH or when formulating custom fertigation solutions from stock chemicals, separate injector heads are necessary (Figure 2A). For example, calcium and sulfate cannot be mixed in the same stock solution tank because they form an insoluble precipitate (gypsum) that can plug up the injector or irrigation nozzles (Figure 2B). A list of incompatible fertilizer chemicals can be found in Landis and others (1989).

Water quality - The amount of dissolved chemicals or particulate matter suspended in your water supply must also be considered before purchasing an injector. With

Figure 2 - Fertilizer injectors with multiple heads, such as the Anderson Ratio:Feeders® (A), are necessary when using more than one fertilizer stock solution. In stock solutions, high fertilizer concentrations cause chemical reactions that form insoluble precipitates (B) that can plug up the injector or irrigation nozzles.



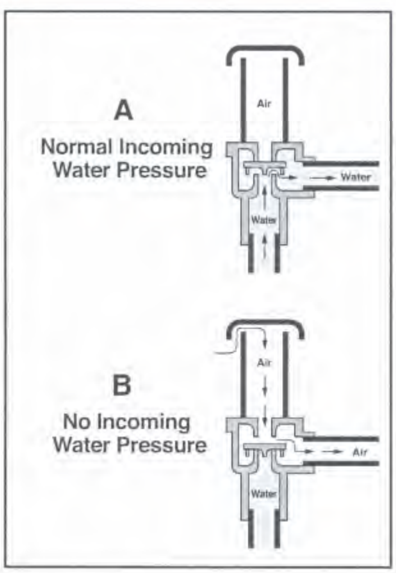
the simpler venturi-type injectors water quality isn't as much of an issue but, with more sophisticated injectors, high amounts of sediment or very hard water can cause excessive wear of the pump mechanism.

Mobility - Fertilizer injectors are typically installed in a permanent protected location, such as a headhouse, where the fertilizer solutions can be mixed and the stock solutions stored. These injectors are plumbed directly into the main irrigation line with valves and a bypass to allow normal irrigation. Some injector models can be mounted on a dolly or cart with quick-connections so that they can be used at several different locations.

Installation of Fertilizer Injectors

When permanently installing a fertilizer injector, we recommend the following. First, install injectors in the headhouse or other insulated building to prevent freezing damage and wear from exposure to the elements. Second, install a filter in the water supply line before the injector to filter debris and reduce wear. Third, install water pressure gauges before and after the filter — a large difference in the pressure readings means the filter is plugging up (Pennisi and Kessler 2003). Plumbing codes require that all potable water systems be protected with a backflow prevention device to insure that contaminated water is not accidentally mixed with water that is used for human consumption. Injecting any chemical without backflow prevention is against the law. Backsiphoning occurs when negative water pressure causes contaminated water to be sucked back into the water supply line. The most commonly used backflow preventer is the vacuum breaker (Figure 3). Under normal water pressure, the valve remains closed (Figure 3A); however, if the pressure in the supply line drops below a predetermined level, the check valve will close and shut off the water supply (Figure 3B). Backflow devices should be installed between the last control valve of the supply system and the fertilizer injector (Koths and others 1976).

Figure 3 - Vacuum breakers are one type of backflow device that prevents water that has been mixed with fertilizer from being sucked back into the water supply line (modified from Koths and others 1976).



Scheduling Fertigation

Two basic schedules for applying liquid fertilizers are constant and periodic. The application of a dilute fertilizer solution each time the crop is irrigated is known as constant fertilization (Landis and others 1989), and the concentration of this applied fertilizer solution is exactly the nutrient concentration desired in the growing medium solution. Periodic fertilization consists of applying a more concentrated fertilizer solution according to some fixed schedule, such as once a week or every other irrigation. The applied fertilizer solution during periodic fertilization may therefore be several times more concentrated to allow for the dilution that occurs during subsequent irrigations. Because periodic application applies a more concentrated solution, growers should rinse crop foliage with irrigation water following each fertigation, as well as carefully monitor to avoid fertilizer salt build-up in the growing medium. An example of a periodic fertilization schedule is given in Table 2. One option is to use continuous fertigation early in the growing season to force growth and build-up plant nutrient reserves, and then change to periodic fertilizer applications to finish the crop. In one study, early season continuous fertigation followed by late season weekly fertigation reduced fertilizer costs by approximately 50% without any growth loss (Struve and Rose 1998). An alternative method is to fertigate using the exponential fertilization method whereby plants receive proportional amounts of fertilizer relative to their growth rate and size (Dumroese and others 2005).

Table 2 - Periodic fertigation schedule for the USDA Forest Service Nursery at Coeur d'Alene, ID

Plant Growth Phase	Timing (weeks)	Type of Fertilizer	Frequency
Germination	0 to 4	H_3PO_4	As needed
Establishment	4 to 8	7-40-17	Every irrigation
Rapid Growth	8 to 12	20-7-19	Every other irrigation
Hardening	12 to 14	4-25-35	Every third irrigation
Pre-Shipping	Prior to harvest	20-7-19	Once

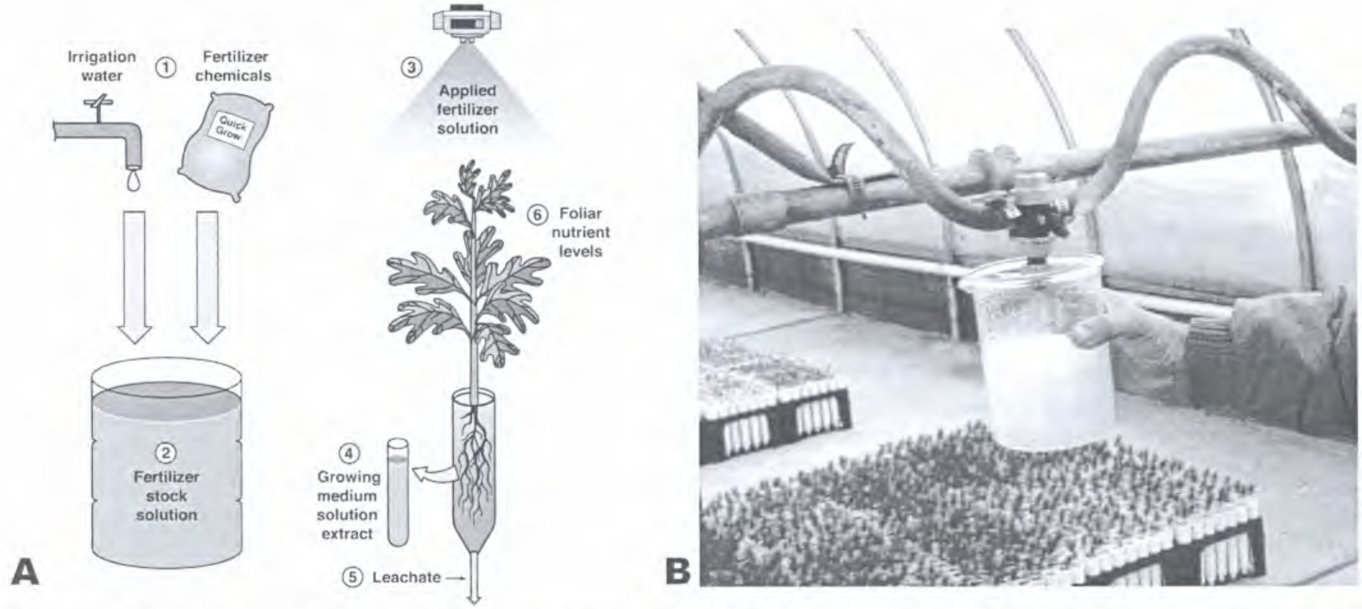


Figure 4 - Checking the electrical conductivity at each stage of the fertigation process (1-5) ensures that the injector if working properly and regular foliar analysis (6) proves that your crop is receiving the proper levels of all mineral nutrients (A). The most critical check is the applied fertilizer solution that goes on your crop (B).

The best way to determine when to fertigate is to carefully monitor plant growth and foliar nutrient levels. Accumulating test results in a spreadsheet program along with seedling growth data allows easy analysis and creates a permanent database that only improves as you gain experience with each crop. As growth versus nutrient curves are developed, it is easy to identify the critical point in the curve when growth begins to flatten out. When this happens, applying more fertilizer will only lead to luxury consumption and, in the case of nitrogen and phosphorus, may cause environmental pollution. Inexperienced growers have the tendency to overfertilize "just to make sure:' and because fertilizer is relatively inexpensive (Landis and others 2005).

How to Monitor Fertigation

Fertigation is a powerful cultural tool but must be carefully monitored. There are two way to check your fertigation program: electrical conductivity (EC) and foliar nutrient levels. The best way to determine if your fertilizer injector is working properly is to monitor the EC of the various fertilizer solutions. EC is a measure of the salinity (total salt level) of a solution and therefore gives an indication of the dissolved fertilizer salts. An EC meter measures the electrical charge carried by the ions that are dissolved in a solution — the more concentrated the ions, the higher the reading. By checking the EC at each step in the process (Figure 4A), you can be sure that your injector is functioning properly.

1. Irrigation water - The base EC of the irrigation water should be monitored monthly, or until you are certain that it does not vary significantly during the season.

2. Fertilizer stock solutions - The efficiency of the fertilizer injector can be checked by making an "applied strength" dilution of the fertilizer stock solution and measuring the EC level. For a 1:100 injector, add one part of stock solution to 100 parts of irrigation water. The EC reading of the diluted fertilizer solution should be approximately the same (within 10%) as the EC of the fertigation solution that is applied to your crop.

3. Applied fertilizer solution - The applied fertilizer solution is by far the most important of the fertilization checks because this solution actually contacts the seedling foliage and enters the root zone. Even if you don't check anything else, be sure to do this test regularly. The applied solution is-collected directly from the irrigation nozzle (Figure 4B) and the EC reading should be approximately the sum of the base salinity of the irrigation water plus the salts added by the fertilizer stock solution. Send a sample of this solution to a testing laboratory and check the levels of the mineral nutrients against your calculated values.

4. Growing medium extract - Samples of the irrigation water and the applied fertilizer solution can be collected directly, but liquid samples must be extracted from the growing medium. The amount of growing medium solution is relatively small and is strongly absorbed, and so special sampling techniques must be used to collect enough solution to measure. The amount of growing medium solution is relatively small and is strongly

absorbed, and so special sampling techniques must be used to collect enough solution to measure. See Landis and Dumroese (2006) for details on the various options.

5. Leachate - The final check involves taking EC readings on the "leachate" solution that drains from the bottom of the containers. Leachate can be obtained by taping a test tube or other container to the drain hole of the container or by placing a tray under a block of containers during fertigation. If the EC of the leachate significantly exceeds the EC of the applied fertilizer solution, then excess salinity is building up in the growing medium and proper leaching is not occurring.

6. Foliar nutrient levels - While EC readings can reveal when overall problems with your fertigation system, the only comprehensive test is to chemically analyze the foliage of your crop and determine its nutrient status. The mineral nutrient concentration of the seedling foliage reflects the actual uptake of all the mineral nutrients. Several commercial suppliers of horticultural products are offering chemical testing of irrigation water, fertilizer solutions, growing media, and seedling tissue at very attractive prices. These labs are equipped with the latest analytical equipment such as the ICAP (Inductively Coupled Argon Plasma) spectrometer and so the tests are done quickly and accurately. They will even telephone, FAX, or email the results back to the nursery so that cultural corrections can be made within a matter of days. Interpretation of foliar tests can be intimidating, but general standards and helpful hints can be found in Landis and others (2005).

Summary

Fertigation is one of the most efficient ways for growers to fertilize their crops because all the essential mineral nutrients are applied at their ideal concentration and in the proper balance. In addition, fertigation does not suffer from the delayed response of solid fertilizers because the nutrients are already dissolved in water and can be quickly absorbed by the roots. Most growers use some type of injector to mix concentrated fertilizer solution into the irrigation system and a wide variety of injectors are available to meet the needs of any size of nursery. Injectors must be properly installed with a backflow device to prevent siphoning of liquid fertilizer back into the water source. Fertigation can be applied with each irrigation or at scheduled intervals; the choice will depend on crop response and the risk of excessive nutrient runoff. A well-designed fertigation system can be monitored at several stages in the process to ensure that the injector is working properly and that the plants are receiving the proper amount of fertilizer.

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Managing surplus or holdover nursery stock

By Thomas D. Landis

So, you've survived another hectic lift-and-pack season but you are left with some surplus or "holdover" plants. Maybe your sowing factors were a little too generous or you overestimated the market for a particular species. Sometimes, poor outplanting site conditions or operational problems means that some stock must be held over for another season. Surplus plants can also show up during grading. Sowing problems, poor weather or cultural shortcomings can result in perfectly good plants that don't meet grading specifications. Overly dense seedbeds produce stunted plants that lack the desired stern diameter, or excessive fertilization produces excessive height growth. What about the large plants that exceed both height and stem diameter specifications? These are often the genetically superior plants that you just hate to throw away. Even if you were aware of the surplus and didn't harvest the stock, you can't leave them in the seedbed or in the containers for too long.

One of the most difficult concepts for novice nursery managers and their customers is that, unlike many products, plants have a shelf-life. Nursery stock is at its peak quality when the plants are harvested and graded and, ideally, they can be shipped and outplanted soon afterwards. Of course, that often isn't possible so the plants must be placed in some sort of storage that maintains that quality. In the days before refrigerated storage, bareroot nurseries "heeled-in" their stock but this mainly protected the roots from desiccation and eventually plants would break bud. Early container nurseries tried to maintain plant quality by placing their stock in lathhouses or other shaded storage, but again, this was a short-term solution. Eventually, the plants would begin to grow and quality would suffer. Refrigerated storage will maintain plant quality for months but eventually, if you can't sell or ship them, something must be done.

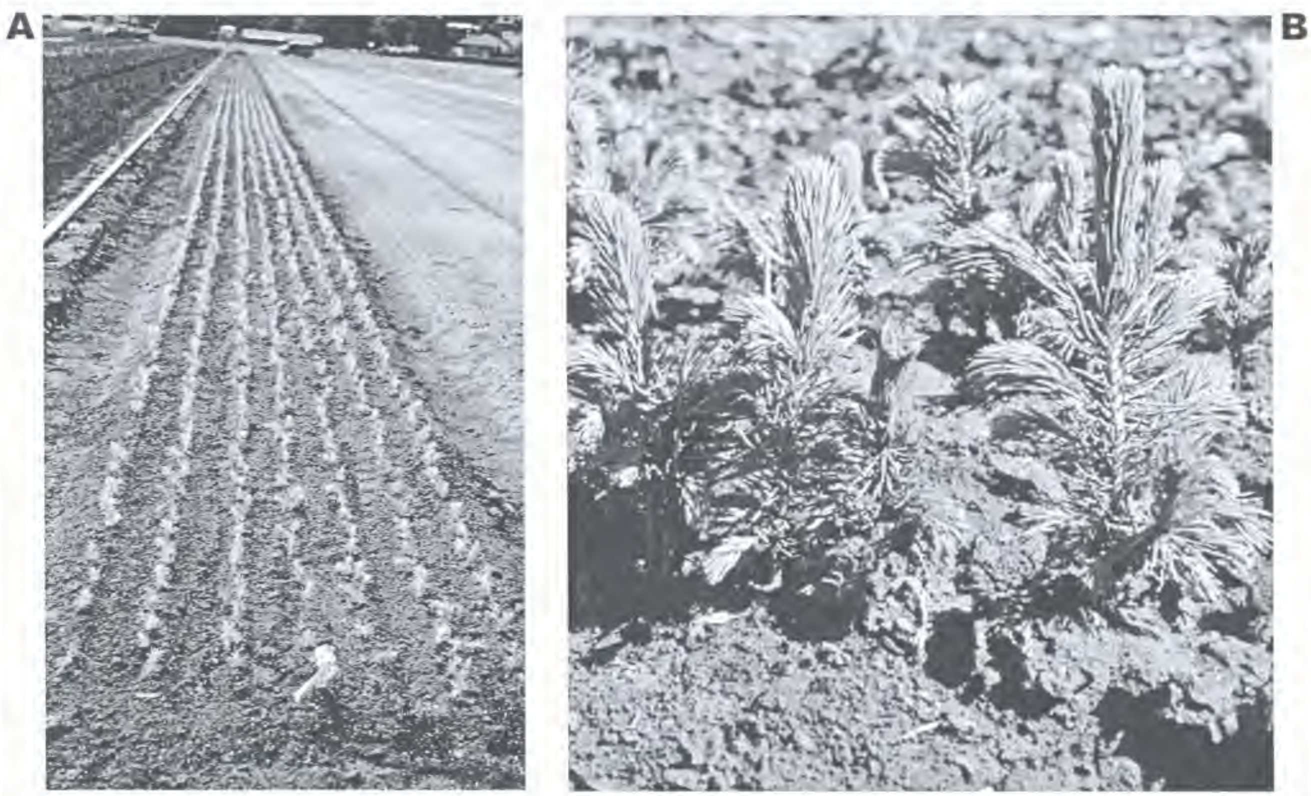

Figure 1 – The best option for surplus or holdover bareroot stock is to root prune and transplant them (A); transplanting increases in-row growing space, which produces greater stem diameter (B).

One of the greatest challenges in nursery management is what to do with plants that have reached target size but haven't been sold or shipped for outplanting. Surplus or holdover stock happens in both bareroot and container nurseries but, as we will see, is a much greater problem in containers.

Bareroot stock — If the surplus plants are still in the ground, you need to evaluate the seedbed density. Seedbeds that are not too dense and still have lateral room to grow can be root pruned and/or wrenched to slow shoot growth, develop a more fibrous root system, and increase stern diameter. In most cases, however, plants are already too dense and would become stunted if left in place for another season. Overly dense crops are also an ideal breeding ground for fungal pathogens such as *Botrytis cinerea.* So, the best option is to harvest the plants, grade, and transplant them (Figure 1A). These plants and stock that is already in storage will have to be root pruned because the target root length for outplanting is much too long for transplanting. Transplanting increases growing space with the row, which produces plants with greater stem diameter (Figure 1B). The greatest challenge will be to keep the shoot-to-root ratio in balance, so these transplants will have to be root pruned or wrenched, which will also increase root fibrosity.

Container stock – Container nursery culture has lead to increased growth rates because of the greater control over most potentially limiting environmental factors. The challenge comes when we want to stop that growth, especially in roots because they don't go dormant. Shoots can be coaxed into dormancy by cultural manipulations of daylength (blackout), mineral nutrition, and water supply, but how do you stop roots from growing? The only way to do this is with cold temperatures, which is why refrigerated storage has become so popular (Landis and others 2010). Nurseries in milder climates that use open or sheltered storage can have a serious problem because roots continue to grow even after shoot growth has stopped. Tropical nurseries suffer the greatest risk of plants becoming "rootbound" because their stock never goes dormant.

Rootbound nursery stock can be defined as plants that have grown too large for their containers, resulting in severe matting and tangling of the root system (Figure 2A).

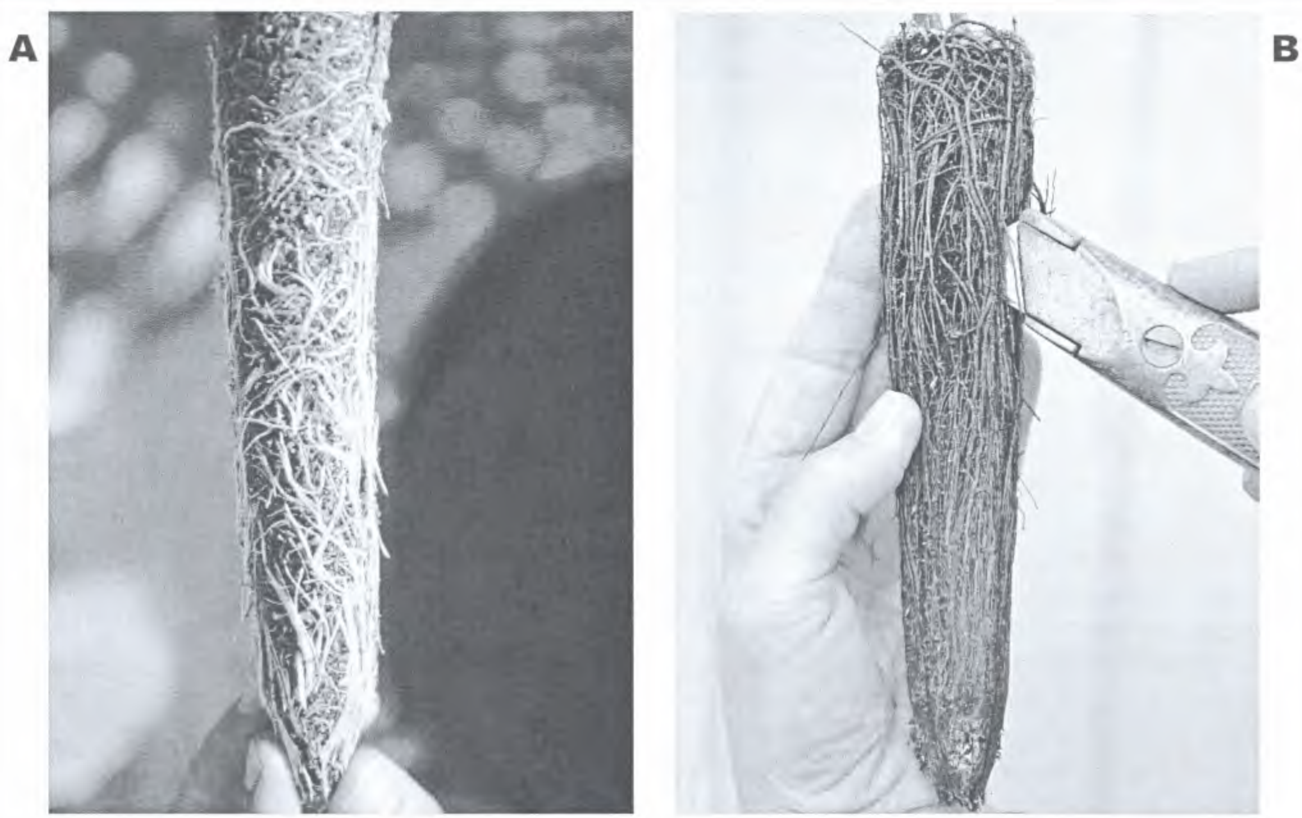

Figure 2 – When container plants have been held too long, they become "rootbound" (A). Transplanting them to bareroot beds or larger containers after making vertical cuts along the rootplug (B) is the recommended practice to hold them over for another season.

Observations have related rootbinding to the length of time that the plant has been in the container (Balisky and others 1995). Logically, the larger the container, the longer it takes for the plant to become rootbound. But time alone is not the only controlling factor, because root growth is also affected by cultural conditions at the nursery. A species growing rapidly in one nursery will become rootbound faster than the same species growing more slowly in another nursery. Similarly, a species in a large container given large amounts of fertilizer may become rootbound as fast as the same species in a smaller container given smaller amounts.

The fact that excessive root growth can be a quality issue in container plants has been known for decades. During the early 1980s there was considerable concern about "toppling" of lodgepole pine *(Pinus contorta)* container stock which was proven to be caused by poor root egress after outplanting (Burdett and others 1986). This lead to the development of copper-coated containers and then to sideslit containers which encourage roots to egress all along the length of the plug instead of just at the bottom. Trials into extending the growing period to produce larger stocktypes also resulted in plants with excessive root biomass for their respective container volumes. Whatever the cause, container plants that have plugs with high root densities suffered poor survival and growth for several years after outplanting (Salonius and others 2002).

How to characterize rootbound plants has been a challenge. South and Mitchell (2006) propose a "rootbound index" based on root-collar diameter divided by container diameter or volume, but this index must be calculated for each container type. From an operational standpoint, establishing a maximum stem diameter along with a visual assessment of root binding might be the most practical system (Landis and others 2010).

Okay, what do you do if your container plants have become rootbound? The best option is to transplant into larger volume containers or into bareroot beds. In fact, the relatively new plug+one stocktype was originally developed as a way to hold over container seedlings (Hahn 1984). If you want to keep your plants as container stock, then you can just transplant into another container that is large enough to support new root growth. It's a good idea to cut the root plug from top to bottom at a couple of places as well as trim the roots at the drainage hole (Figure 2B). This process is time consuming but encourages new root growth all along the length of the original root plug.

Summary

Surplus or holdover stock is sometimes inevitable hut careful planning and good communication with customers can reduce the instances. Bareroot stock should have their roots trimmed and then be transplanted; the plants may need to be pruned or wrenched to maintain a good shoot-to-root ratio. Holdover container stock is more of a challenge because the plugs can become severely rootbound. Make vertical cuts along the root plug before transplanting them to bareroot beds or containers large enough to promote new root growth while retarding excessive shoot growth.

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Late-Season Fertilization of Nursery Stock

By Diane L. Haase and Thomas D. Landis

Regulating seedling nutrient content through fertilization is a key component of nursery culture for both bareroot and container stock. Typically, fertilizers are applied early in the growing season to fuel active shoot growth. Then, fertilization (especially nitrogen) is reduced or stopped to induce budset and promote development of cold hardiness, usually during July through September depending on species, seed source, and stocktype specifications. However, a significant amount of root and stem growth can still occur late in the growing season as long as temperatures remain within favorable ranges. This increase in biomass late in the growing season can lead to nutrient dilution within the plant unless more nutrients are supplied through fertilization. If nutrient concentrations drop below the adequate range, there may be inadequate reserves for vigorous growth following outplanting. However, many growers are concerned about the traditional belief that fertilizing too late in the season will cause budbreak, stimulate additional shoot growth, or delay or reduce cold hardiness.

To prevent nutrient dilution, some nurseries apply late-season fertilizers after shoot growth has ceased (Figure 1A). Because seedlings are actively growing roots well into the fall, there is great potential to increase seedling nutrient content with fertilization. Nutrient loading is a relatively recent cultural practice in which late-season fertilization is used to increase seedling nutrient reserves with the objective of promoting additional growth after outplanting. Nutrient concentration in nursery plants follows a classic uptake curve and nutrient loading is the uptake of nutrients beyond the adequate range, but not so much that toxicity is reached (Figure 1B). This enhanced internal nutrient reserve is thought to increase root egress and promote

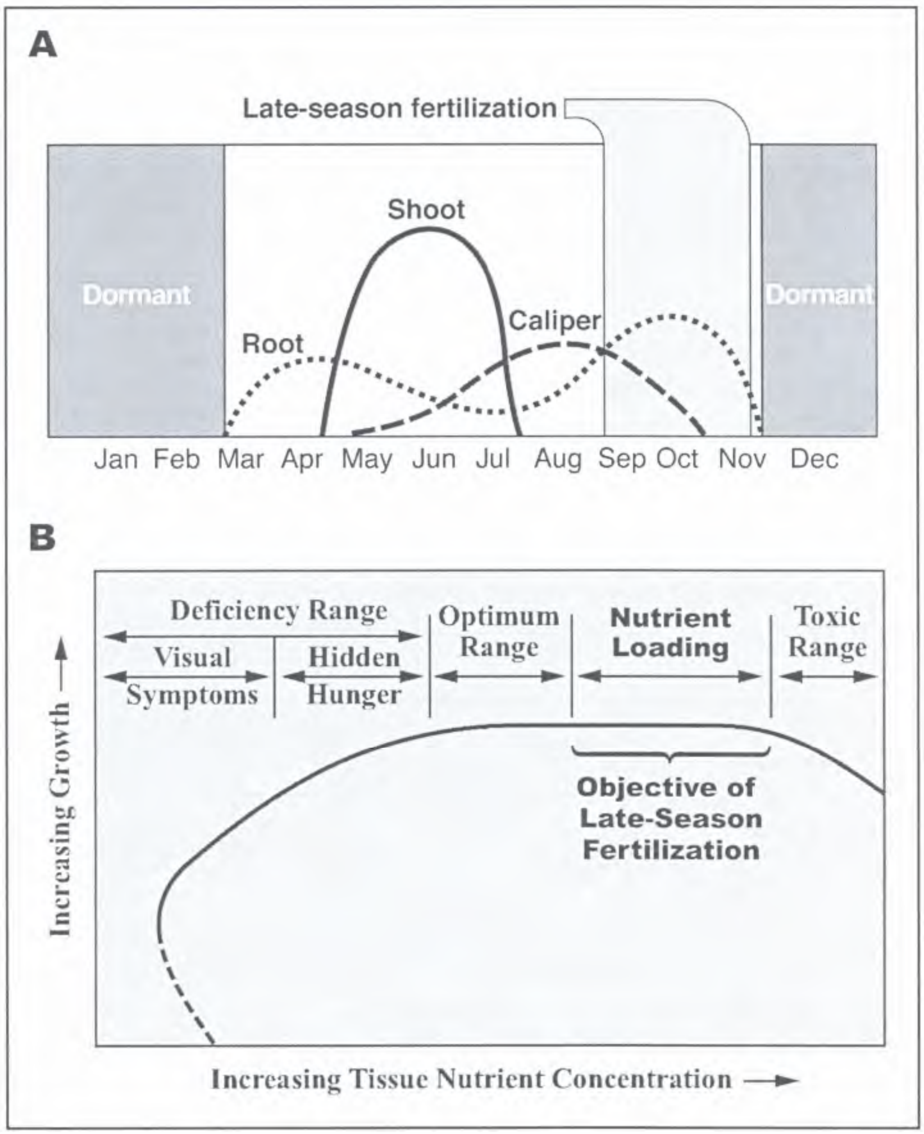

Figure 1 – Late season fertilization is applied after shoot growth has ceased (A) with the objective of "loading" the plants with extra mineral nutrients (B) to promote better growth after outplanting. (B, modified from Chapman 1967).

faster shoot growth immediately following outplanting. Nutrient loading is promoted to improve seedling field performance, especially on nutrient-poor sites or sites with heavy competition (Timmer 1997).

Numerous research studies on late season fertilization have been conducted, and results have been variable to say the least (Table 1). One explanation for this variation is that studies have been done on different crops,

Table 1 - Summary of research studies on with late-season fertilization of conifer seedlings

Source	Stocktype	Type and Rate of fertilizer	Application timing	Effects on nursery stock
Benzian and others (1974)	Bareroot	NH_4NO_3+$CaCO_3$ or K_2SO_4 at 62 or 125 lb/ac	Early September	Increased foliar nitrogen (N) concentrations; earlier budbreak; increased growth of spruce but reduced survival of fir
Birchler and others (2001)	Bareroot	NH_4NO_3+K_2SO_4 or $(NH_4)_2SO_4$+KCL at 0 to 285 lb N and K/ac	September to November	Increased foliar N; root growth potential and cold hardiness unaffected; earlier budbreak; no effect on outplanting performance
Boivin and others (2002)	Container	Soluble 20-20-20 NPK at 6 or 12 mg N per seedling	During hardening period	N, P and K uptake increased up to 164, 70 and 32%, respectively; greater biomass; lower shoot-to-root ratio
Boivin and others (2004)	Container	Soluble 20-20-20 NPK at 0 to 48 mg N / seedling	9 weeks after bud set	Increased N uptake and growth after outplanting; reduced survival at the highest rate
Hinesley and Maki (1980)	Bareroot	Macronutrient fertilizers at 150 N lb/ac	Late October	Increased seedling size and foliar nutrient concentrations
Irwin and others (1998)	Bareroot	NH_4NO_3 at 51 lb N/ac applied 0 to 3 times	November to December	Increased N concentration with no change in morphology; increased first-year field height and survival
Islam and others (2009)	Bareroot	NH_4NO_3 at 0 to 80 lb N/ac	Mid-September	Increased shoot height, bud size, number of needle primordia, N concentration, and cold hardiness
Montville and others (1996)	Container	foliar fertilization (27-15-12) at 324 to 972 ppm	Twice weekly during budset	Increased stem diameter, bud length, shoot biomass, and N concentration
South and Donald (2002)	Bareroot	0, 134 lb/ac N, 134 lb/ac of N + 134 lb/ac of P, or 134 lb/ac of K	Early October	Increased N concentration with no effect on morphology; variable effects after outplanting
Sung and others (1997)	Bareroot	NH_4NO_3 at 0 to 36 lb/ac	Mid-September	Fewer culls at high rate; increased first order lateral roots and dry weights
van den Driessche (1985)	Bareroot	Macronutrient fertilizers at 0 to 71 lb N/ac	July to October	Increased N concentration and new roots; higher relative growth rate in sand culture but not in artificial soil; earlier budbreak
VanderSchaaf and McNabb (2004)	Bareroot	NH_4NO_3 at 0 to 178 lb N /ac	January	Increased N concentration; no effect on morphology; greater growth after outplanting
Williams and South (1992)	Container	$(NH_4)_2HPO_4$ at 0 to 180 lb N/ac	September to November	Fertilization did not delay the progression of the bud dormancy cycle; temporary effects on cell division

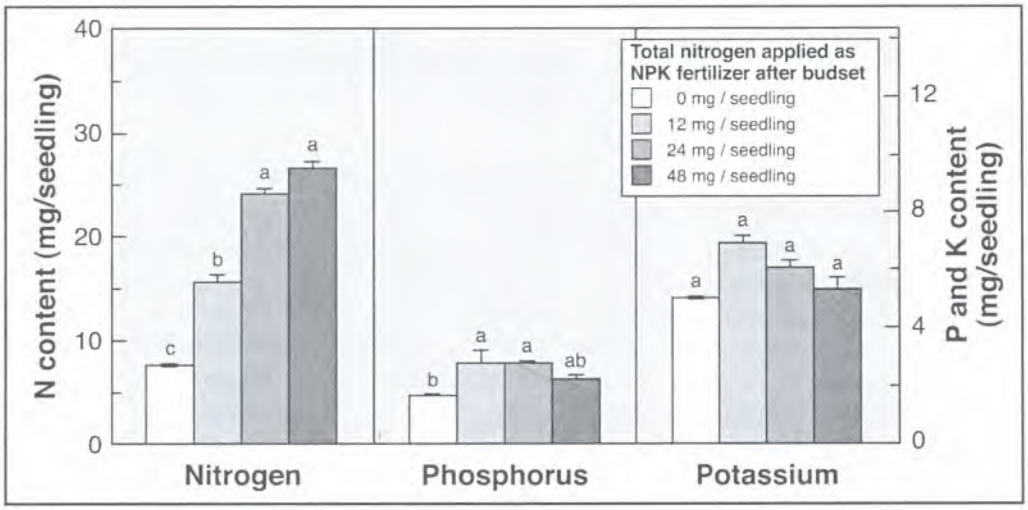

Figure 2 – When black spruce (Picea mariana) seedlings were loaded with NPK fertilizer, nitrogen showed the greatest increase. For each nutrient, bars with the same letter are not statistically different ($\alpha \leq 0.05$). Adapted from Boivin and others (2004).

with different fertilizers, at different rates, and applied at different times. Therefore, it is impossible to generalize about the effects of late season fertilization on your particular crop. However, one consistent finding is that late season fertilization greatly increases seedling nutrient concentrations, especially nitrogen (Figure 2). The effects of late season fertilization on seedling morphology, physiology, and subsequent growth after outplanting are also variable, but two out of three studies report some type of positive response. In some cases, seedling size increased in the nursery (Boivin and Timmer 2002; Hinesly and Maki 1980; Islam and others 2009; Montville and others 1996; Sung and others 1997) but no additional growth was measured in other studies (Boivin and others 2004; Irwin and others 1988; South and Donald 2002; VanderSchaaf and McNabb 2004). Late season fertilization can affect budbreak the following year; several studies report that budbreak was earlier in the following season for nutrient-loaded seedling compared to control seedlings (Benzian and Freeman 1974; Birchler and others 2001; van den Driessche 1985). After outplanting, growth of seedlings with increased nutrient reserves was found to be greater in some cases (Benzian and Freeman 1974; Boivin and others 2004; Hinesley and Maki 1980; Irwin and others 1988; South and Donald 2002; van den Driessche 1985; VanderSchaaf and McNabb 2004) but was unaffected in others (Benzian and Freeman 1974; Birchler and others 2001; South and Donald 2002; van den Driessche 1985). In a few cases, very high fertilization rates resulted in reduced survival after outplanting (Benzian and Freeman 1974; Boivin and others 2004; South and Donald 2002) indicating the need to avoid excessive nutrient loading into the toxic range (Figure 1B).

Late season fertilizer applications must be carefully scheduled to avoid negative effect on phenology. By applying fertilizers after plants have been exposed to cold nights, the chances of stimulating Lammas growth will be lessened. One of the biggest concerns about late season fertilization is that it would decrease cold hardiness. One study found that cold hardiness is unaffected by properly applied, late-season fertilization (Birchler and others 2001) and, in fact, the development of cold hardiness can actually be impaired if plant nutrient concentrations are too low.

Summary

Late-season fertilization has potential for improving seedling quality and outplanting success but nurseries should conduct trials on fertilizer formulations and rates in order to develop an optimum treatment for a specific crop. Monitor mineral nutrient uptake through seedling nutrient analysis to ensure that fertilization treatments are effective, and prevent overfertilization which can reduce plant quality and accelerate nutrient runoff.

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Bird Damage to Sown Seeds or Emerging Seedlings

By Thomas D. Landis

It's spring so most growers are sowing their crops or will be doing so in the next couple of months. Many things can go wrong during sowing (Figure 1), and all gardeners know the anxiety of waiting for those germinating plants to "poke their heads" out of the soil or growing medium. Seeds are small packets of high-energy food and therefore are especially attractive to birds. Trying to keep these critters from eating all your crop seeds is one of those concerns that man has faced since the beginning of recorded time.

It is difficult to quantify the overall impact of animal damage because the incidents are generally episodic. Bird predation is often due to migrating flocks, which can do severe damage in a short time. One nursery that participated in the Container Nursery Survey reported that from 25 to 50% of their sown seeds were eaten by goldfinches (Landis and others 1989). Bird damage is often localized -- losses varied from 0 to 75% of ponderosa pine (Pinus ponderosa) seeds in one bareroot nursery (Landis 1976).

Current information on bird predation is hard to locate but the best sources are websites. For instance, up-to-date information on all types of animal damage can be found at the Internet Center for Wildlife Damage Management, which is a non-profit, grant-funded site that provides research-based information on how to responsibly handle wildlife damage problems (Vantassel 2010). On that site, you can download Prevention and Control of Wildlife Damage, which contains information on diagnosing and controlling all types of widlife pests including birds (Hygnstrom and others 1994). Not much has been published on bird predation in forest, conservation, and native plant nurseries so much of this article was based on Volume Five: Nursery Pests and Mycorrhizae of the Container Tree Nursery Manual series (Landis and others 1989).

Hosts - Birds will eat seeds of all conifer and native plant species but prefer the large-seeded pines such as white pine, sugar pine, and pinyon. Crows and ravens can damage seed beds of large hardwood seeds such as oaks.

Symptoms/damage - If seeds cannot be located in the container or seedbed, but the seed covering has been scattered around, then bird predation is a possibility (Figure 1A). However, it can be difficult to distinguish between bird and rodent damage. Birds generally eat seeds immediately leaving spent seedcoats, whereas rodents often cache uneaten seeds. Rodents feed mostly at night, whereas birds usually feed during the day. Rodent predation can occur in open and closed growing areas, but bird predation is more common in open compounds. Birds also cause clipping injury to emerging seedlings by feeding on the seed coat that clings to the cotyledons (Figure 1 B). Larger seedlings can sometimes recover from clipping injury, although severely damaged

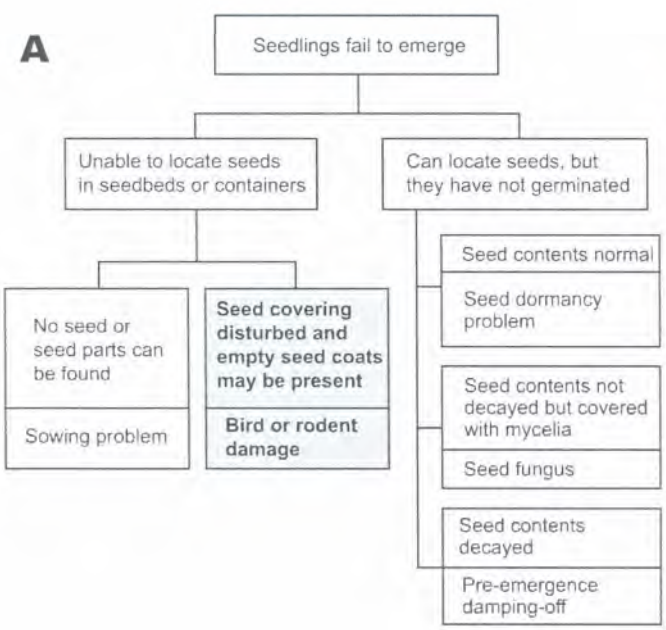

Figure 1 - A damage key is helpful to separate bird predation from the many things that can happen to newly-sown seeds (A). Besides consuming seeds, birds can clip the tops of germinants, which usually results in their death (B) (A, modified from Landis and others 1989).

Figure 2 – Netting has been effective in preventing bird damage in both bareroot (A) and container nurseries. Noise repellents, such as the propane cannon (B) work initially, but birds soon become tolerant.

germinants are weakened and prone to other pests, such as damping-off fungi.

Management - Bird predation is best controlled through prevention: exclusion through proper growing area design and use of screens, and elimination of suitable habitat around the growing area. Control measures include (Fuller and others 1984):

1. Netting - Plastic bird netting is available in several lengths and widths. It is applied over sown containers or seedbeds (Figure 2A) and physically protects seeds and germinants until they are established. Wire hoops support the netting and the mesh size is large enough to allow rain or irrigation to reach the plants. A system for mechanically applying bird netting to bareroot seedbeds has been developed (Skakel and Washburn 1989).

2. Trapping and baiting - Birds are opportunists and can sometimes be lured away from crop seeds if you supply another more desirable food source away from the nursery. Surplus seeds can be scattered around to attract birds and keep them from reaching the crop seeds.

Table 1 - Characteristics of chemical bird repellents used in forest and conservation nurseries *

Product	Active Ingredient	Remarks
Dithianon	Anthraquinone	A quinone fungicide that is registered by the EPA for bird control. It also occurs naturally in some plants, such as aloe, senna, rhubarb, and Cascara buckthorn
Mesurol® 75 W	Methiocarb	Registered by EPA as an insecticide and molluscide. Commonly used by homeowners to kill snail and slugs
Thiram® 50 WP, Arasan, Tersan 74	Dithiocarbamate	Registered by EPA as a fungicide that is applied as a seed treatment
Rejex-It, Bird Shield™	Methyl anthranilate	Several formulations are available that make birds sick without killing them. Active ingredient is found in concord grapes, and is used as a flavoring in grape soda
Hot Sauce® Animal Repellent, Deer Away	Capsaicin	Available commercially in concentrations from 2.5 to 6.2% Homemade formulations are made by grinding dried, ripe *Capsicum frutescens* chili peppers into a fine powder and mixing with a solvent.

* Modified from Colorado State University Extension, 2007. All pesticide information is subject to change so be sure to check the labels or on-line sources

3. Chemical repellents - You might think that the simplest and most effective way to prevent bird predation of seeds is to apply a repellent before sowing. Several chemicals have been used to repel birds in nurseries (Table 1).

Unfortunately, birds and mammals apparently have large differences in tolerances to various repellents. For instance, pen studies have shown that capsaicin products have effectively repelled deer and elk but other observations have shown that birds will readily consume seeds treated with capsaicin concentrations as high as 2% (Colorado State University Extension 2007).

4. Visual repellents - Altering the appearance of seeds may help delay or prevent predation. Aluminum powder has traditionally been used in forest nurseries to keep conifer seeds from sticking together during mechanical sowing. More recently, some nurseries coat their seeds with DayGlo® paint pigment to make sown seeds easier to see in the furrow or container. No published research exists, but changing the color of seeds may be an effective bird repellent.

5. Noise repellents - Many devices have been used for frightening birds including portable propane cannons (Figure 2B). While initially effective, most birds eventually become accustomed to the noise.

A good source for all types of animal control chemicals and equipment can be found on-line (Hygnstrom and others 1994).

Final Thoughts

Considering the cost of seed and the amount of time and energy expended during the sowing process, it only makes sense to try and protect newly-sown crops from bird predation:

1. Effectiveness is a factor of motivation and habituation. Repellents are less effective when birds are hungry or other sources of food are unavailable. All animals are creatures of habit, and habituation can complicate repellent efforts.

2. Phytotoxicity, worker safety, and environment hazards. Any chemical applied to seeds has the potential to adversely affect seed germination or young seedlings. Pesticides registered as safe for other crops may not have been tested on trees and other native plants. The repellents listed in Table 1 vary widely in their potential toxicity to nursery workers or other animals.

3. Availability & cost. Most commercial repellents are readily available through garden centers or reforestation suppliers, and their cost is minimal compared to the potential crop damage. Others, such as pepper sprays, can be homemade.

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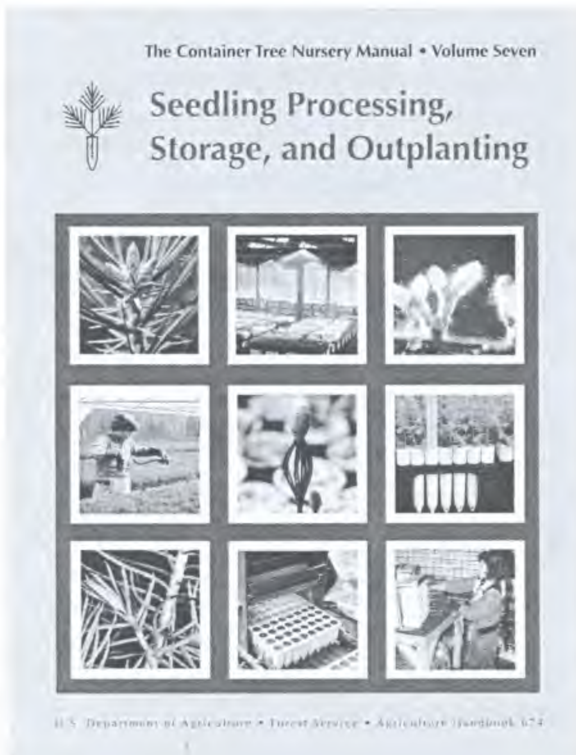

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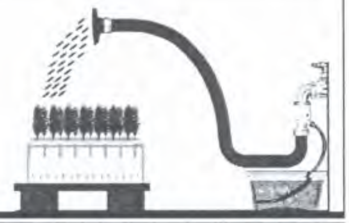

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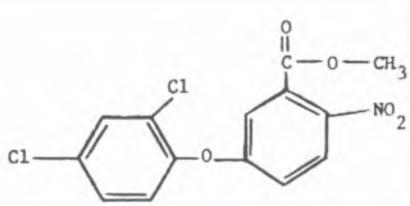

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